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VOLUME I

LEVEL II

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AIRCRAFT TRANSPARENCY FAILURE & LOGISTICAL COST ANALYSIS
VOLUME I PROGRAM SUMMARY

S. S. Brown

Rockwell International
Los Angeles Division
815 Lapham Street
El Segundo, CA 90245

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Final Report June 1977 – September 1978

Approved for public release; distribution unlimited.

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE, OHIO 45433

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Charles A. Babish III
Laboratory Contract Manager

Richard J. Dobbek
Group Leader, Crew Escape and Subsystems Branch

FOR THE COMMANDER

Ambrose B. Nutt
Director
Vehicle Equipment Division

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The concern for increasing costs in the maintenance of transparency systems has prompted the Air Force Flight Dynamics Laboratory to sponsor this study contract. The objective of this study is to identify the high-cost, high-maintenance transparency components, identify cause of failures, and recommend corrective programs to reduce cost of ownership to the Air Force Logistics Command.

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20. ABSTRACT (Continued)

The study involved the review of 20 selected aircraft in current Air Force inventory to establish an extensive data base relating to transparency maintenance activity and associated logistical support costs. During this study, a collection of detailed design characteristics, methods of construction, test and qualification, and costing information was assembled. From these data, the basis for design improvements were determined. Field audits of Air Logistic Centers, selected Air Force operational bases, airframe manfuacturers, and transparency suppliers were made. Inquiries were made to identify and evaluate the available facilities, maintenance programs and procedures, and testing capabilities. These data, in conjunction with the design characteristics, were used to determine the impact that aircraft performance, environmental, and weathering factors have on the failures of transparency components. The approach used in the identification of candidate improvements was to focus on the high-cost contributors to maintenance and repair. Trade studies were subsequently generated to determine the design improvements that resulted in reduced logistical costs. The study results are presented in this report.

FOREWORD

The study presented in this report was performed by the Los Angeles Divison (LAD) of Rockwell International Corporation (Rockwell) under U.S. Air Force, AFSC, ASD, Wright-Patterson Air Force Base Contract F33615-77-C-3060. This study was performed for the Recovery and Crew Station Branch (FER), Vehicle Equipment Division (FE), Air Force Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio under Project 2402 "Vehicle Equipment Technology", Task 240203 "Aerospace Vehicle Recovery and Escape Subsystems", Work Unit 24020302 "Aircraft Transparency Failure and Cost Analysis". Mr. C. A. Babish III (AFFDL/FER) was Laboratory Contract Manager.

This program was started 15 June 1977 and submitted by the author for approval 29 September 1978. The report was released under NA-78-604 by Rockwell for internal control.

Mr. W. D. Dotseth was the Program Manager for Rockwell. Contributing technical personnel were S. S. Brown, Deputy Program Manager, Engineering Specialties; O. F. Niedermann, Engineering Specialties; H. L. Hayes, Transparency Design; R. H. Ewald, Jr, Operation and Proposals Estimating; and W. H. Hatton of Reliability.

The author wishes to thank the field audit contacts in the Air Force, in the airframe industry, and transparency suppliers for their cooperation and valuable assistance in collection of maintainability and logistical support data.

This report is assembled in three separate volumes to provide a presentation of study results that permits easier access to and handling of the data collected and presented herein. The separate volumes are:

Volume I - PROGRAM SUMMARY
Volume II - DESIGN DATA AND MAINTENANCE PROCEDURES
Volume III - TRANSPARENCY ANALYSIS

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LIST OF ABBREVIATIONS

A/C	Aircraft
ACI	Analytical Condition Inspection
AEDC	Arnold Engineering Development Center
AFB	Air Force Base
AFFDL	Air Force Flight Dynamics Laboratory
AFH	Flight Hours (From AFM 66-1)
AFL	Number of Flights (From AFM 66-1)
AFLC	Air Force Logistics Command
AFM	Air Force Manual
AFM 66-1	Maintenance Management System
AFM 65-110	Standard Aerospace Vehicle and Equipment Inventory, Status, and Utilization Reporting
AFM 127-1	Accident/Incident Data
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AFTO	Air Force Technical Order
ALC	Air Logistics Center
AMS	Avionics Maintenance Squadron
ASTM	American Society for Testing and Materials
AT	Action Taken
ATF/LCA	Aircraft Transparency Failure and Logistics Cost Analysis
BLIS	Base Level Inquiry System
CON-C	Condemnation Costs
CRC	Cost Reduction Curve
DCM	Deputy Commander - Maintenance
DDCC	Delaminations, Deterioration, Cracks, and Chipping
D056	Product Performance System
D062	Spares Requirement System
DS	Distribution and Supply
EUMR	Emergency Unsatisfactory Materiel Report
FE	Vehicle Equipment Division
FER	Recovery and Crew Station Branch
FH	Flight Hours

FMC	Field Maintenance Cost
FMEA	Failure Modes and Effect Analysis
FMS	Field Maintenance Squadron
FSN	Federal Stock Number
HDP	Hydropress Die
HM, How Mal	How Malfunction
HTF	Heat Treat Fixture
IN	Information Office
INS	Inches
IROS	Increased Reliability of Operational Systems
KFH	Flight Hours (From K051)
KFL	Number of Flights (From K051)
K051	Logistical Support Cost (IROS)
(L)	Left-Hand Side
LAD	Los Angeles Division (Rockwell International)
LB	Pounds
LCC	Life Cycle Cost
LG	Laminated Glass
(L/R)	Left- and Right-Hand Sides
LRU	Line Replaceable Unit
LSC	Logistical Support Cost
MA	Maintenance
MAM	Maintenance Analysis Model Program
MDCS	Maintenance Data Collection System (AFM 66-1)
MDR	Maintenance Demand Rate
MIPS	Material Improvement Projects
MM	Material Management
MMH	Maintenance Man-Hours
MMH/FH	Maintenance Man-Hours per Flight Hour
MMH/MA	Maintenance Man-Hours per Maintenance Action
MTBF	Mean Time Between Failures
MTBMA	Mean Time Between Maintenance Action
MTBR	Mean Time Between Removal

MTBUR	Mean Time Between Unscheduled Removal
MTSL	Master Transparency System List
MU	Wavelength - Millimicrons
NDI	Nondestructive Inspection
NO. (#)	Number
NOC	Not Otherwise Coded
NORM	Not Operationally Ready - Maintenance
NORS	Not Operationally Ready - Supply
NRTS	Not Repairable This Station
NSN	National Stock Number
NTIS	National Technical Information Service
OAFB	Operational Air Force Base
OMS	Organizational Maintenance Squadron
PC	Polycarbonate
P/C	Pilot and Copilot
PDM	Programed Depot Maintenance
P/FFLABORT	Primary Failure Discovered After Flight Abort
P/FGRABORT	Primary Failure Discovered After Ground Abort
PFP	Production Flat Pattern
POMO	Production Oriented Maintenance Organization
PP	Procurement and Production
PPG	Pittsburg Plate Glass Industries
PSC	Packaging and Shipping Costs
PVB	Polyvinyl Butaryl
Q/C	Quality Control
(R)	Right-Hand Side
RAM	Reliability and Maintainability Program
RI/LAD	Rockwell International/Los Angeles Division
ROK	Recheck OK
R&R	Repair and Reclamation
RRS	Repair and Reclamation Shop
SA	Stretched Acrylic
SRC	Specialized Repair Costs

SRD	Steel Rule Die
TCTO	Technical Compliance Technical Order
TO	Technical Order
TT	Task Time
UCLA	University of California at Los Angeles
UMA	Unscheduled Maintenance Actions
USAF	United States Air Force
WBS	Work Breakdown Structure
W/S	Windshield
WUC	Work Unit Code

ALCS	Air Logistic Centers
OC-ALC	Oklahoma City ALC, Tinker Air Force Base, Oklahoma
OO-ALC	Ogden ALC, Hill Air Force Base, Utah
SA-ALC	San Antonio ALC, Kelly Air Force Base, Texas
SM-ALC	Sacramento ALC, McClellan Air Force Base, California
WR-ALC	Warner Robins ALC, Warner Robins Air Force Base, Georgia

SECTION I

INTRODUCTION

INTRODUCTION

The Air Force's continued effort to increase the reliability, and thereby reduce the cost of maintaining aircraft transparency systems (windshield, canopies, cabin windows) has prompted the Air Force Flight Dynamics Laboratory to sponsor this program. It is directed at surveying the maintenance and installation procedures at the five Air Logistics Centers (ALC's) and eight selected Air Force operational bases for the purpose of identifying the high-cost, high-frequency maintenance items of transparency components for 20 selected aircraft currently in the Air Force inventory.

This program is an extension of two previous programs (references 1 and 2) that were conducted to study failure modes, maintenance procedures, and the associated logistical support costs for transparency systems. The extent of the analysis developed in these previous studies was to search historical maintenance and logistical cost records, and categorize the physical transparency characteristics, failure modes, frequency of failures, and costs in a readily identifiable and inclusive statement of the problem.

The intent of this study is to expand the research of the transparency problems in greater depth, identify and recommend changes in maintenance procedures, and recommend design improvements that will reduce failures and cost of maintenance.

Reference 1. J.H. Carlson, Windshield/Canopy/Support Structure (WCSS) Life Cycle Cost and Failure Analysis, AFFDL-TR-115 Air Force Flight Dynamics Laboratory, Wright-Patterson air Force Base, OH 45433, September 1975.

Reference 2. C.S. King, Windshield/Canopy Cost and Failure Analysis, UDRI-TR-76-69, University of Dayton, Dayton, Ohio, October 1976.

BACKGROUND

Continued progress in the science of flight technology and the dramatic increase in performance required of both the current fleet and the next generation of aircraft has driven the cost of maintaining this equipment toward an astronomical figure. Current estimates indicate the cost of maintaining the total Air Force fleet is approaching two billion dollars per year (references 3 and 4). It is for this reason that the Department of Defense is placing greater emphasis on weapon system design-to-cost and life-cycle cost improvements in the area of maintenance and logistical support. An essential part of any aircraft is its transparency system. The large amount of funds being expended on transparency systems is shown in figure 1.

The annual costs are categorized by aircraft type for an eighteen month timespan covering July 1976 through June 1977. The total scaled annual cost of approximately five and one-half million dollars is for the 20 study aircraft. If all models in current inventory were included, the annual cost indicated would be significantly higher. To further demonstrate the huge expenditure, a 10-year projection (figure 2) adjusted for inflation and aircraft attrition indicates that approximately $72,600,000 will be spent. This estimate does not include other models or the new weapon systems that will be phased in during that timespan. The cost data shown in these charts were extracted from K051/"Increased Reliability of Operational Systems" (IROS) data (reference 5).

Reference 3. Department of the Air Force, "USAF Cost Planning Factors, AFR 173-10, Volume I, Headquarters, US Air Force Washington, DC 20330, 6 February 1975

Reference 4. W. D. Dotseth, R. W. Nickel, W. F. Routh, "Low-Cost Study," AFFDL-TR-76-73, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base OH 45433, August 1976

Reference 5. IROS, "Increased Reliability of Operational Systems," K051, AFLC Pamphlet 400-11, Department of the Air Force, Headquarters, Air Force Logistics Command (AFLC), Wright-Patterson Air Force Base, OH 45433, Headquarters, Air Force Systems Command (AFSC) Andrews Air Force Base, DC 20334, 16 August 1974

In view of the large sums being expended in maintaining these transparencies, this study is programed to develop cost-effective design and repair concepts aimed at reducing logistical support costs.

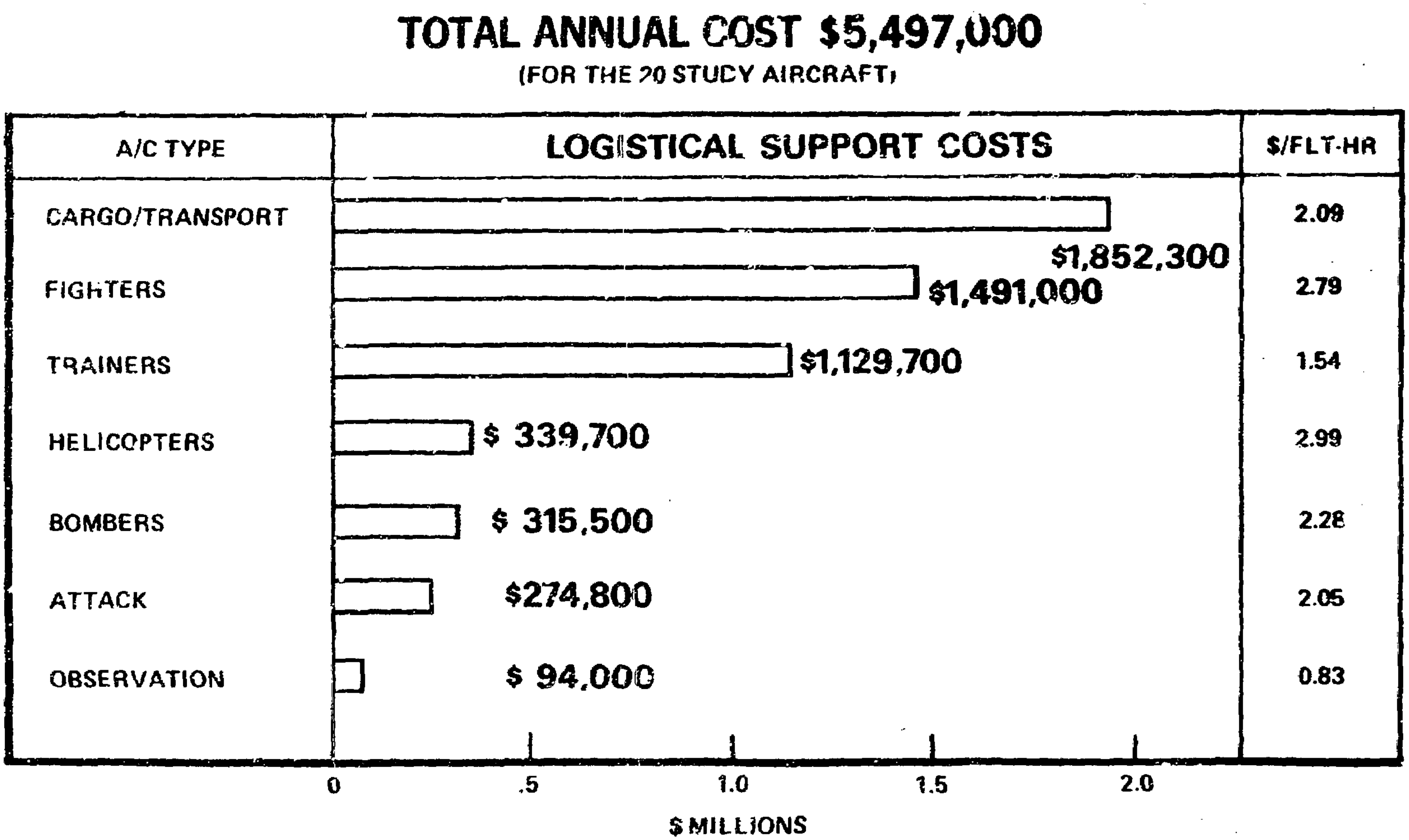


Figure 1. Annual LSC in 1977 Dollars

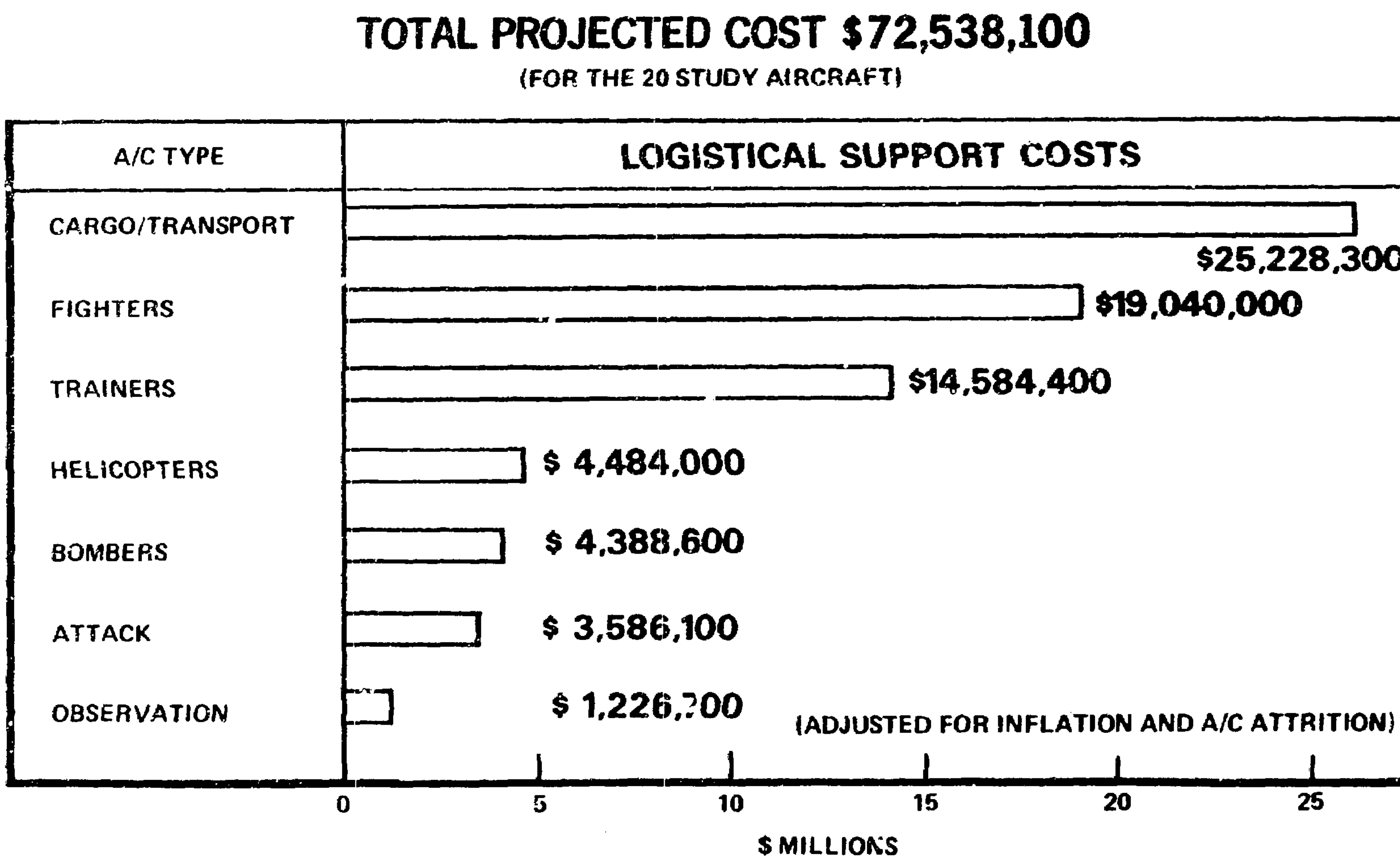


Figure 2. Projected 10-Year LSC in 1978-88 Dollars

SECTION II

REQUIREMENTS AND TASK DESCRIPTION

PROGRAM OBJECTIVES

The objective of this study was to develop a program to reduce logistical costs of transparency systems. It was accomplished by conducting a detailed study of the reliability, maintainability, and logistical support characteristics of 20 study aircraft. The approach was to:

1. Identify high-cost/high-maintenance system components - A search was made to determine those components whose reported maintenance has resulted in an unusually high frequency of failure, and resulted in high maintenance costs. This means was used in selecting the candidates that present the greatest potential in cost reduction.

2. Conduct an in-depth failure analysis - A detailed failure analysis was conducted to determine the failure modes that are causing the greatest incident rate of maintenance actions. Past records of the DO-56 tracking system network (reference 6) were scanned to extract the maintenance information contained in the various data collection programs. These data were assembled to provide a maintenance history of each component.

3. Define the most significant design parameters affecting cost and reliability of transparency systems - During the searching process, a concentrated effort was made to identify the design parameters that significantly affect the functional operations of the transparency components or support systems. Special emphasis was placed on determining the impact on operational cost and reliability.

Reference 6. Department of the Air Force, "Product Performance System (D056)," AFLCM 171-45, Headquarters, Air Force Logistics Command Wright-Patterson Air Force Base, OH 45433, April 1971

4. Recommend corrective programs to achieve significant savings in life-cycle costs - Utilizing this analysis, failure causes were identified and system improvements and recommendation for changes in procedures were proposed. These proposals were thoroughly analyzed and, through trade studies, the cost effectivity of these changes were determined. From these trades, corrective programs that achieve significant savings in life-cycle cost have been recommended to the Air Force.

PROGRAM REQUIREMENTS

The program was a 19-month study, phased in the following three tasks:

Task I - Collection of data/information
Task II - Field audit of AFLC procedures and cost data
Task III - Transparency analysis

Task I, the collection of data and information, provided a baseline of the physical characteristics and design specifics to provide the transparency designer with a means to identify and effect candidate improvements. During this phase, data pertaining to qualification testing and procedures were gathered to support cost trade studies. These data include information to evaluate structural and thermal integrity, reliability, resistance to bird impact, environmental weathering effects, and optical quality factors. The collection of data used as reference material includes the Air Force technical orders that describe the maintenance and repair procedures that are currently in use by both the AFLC and operational bases.

Task II, the field audit of AFLC and selected operational bases, was accomplished to correlate the actual maintenance activity with maintenance efforts recorded in AFM-66-1, Maintenance Data Collection System (MDCS), reference 7. The previous studies made indicated that descriptive data

Reference 7. MDCS, Air Force Manual 66-1, "Maintenance Data Collection System," AFLC/AFSC Pamphlet 400-11, Headquarters, Air Force Logistics Command (AFLC) Wright-Patterson Air Force Base, OH 45433, Headquarters, Air Force Systems Command (AFSC) Andrews Air Force Base, DC 20334, 16 August 1974 contained within AFM-66-1 are not always adequate to fully describe the nature and types of failures recorded. The audits were principally structured to provide the supplementary information through a questionnaire submitted prior to visitation to each facility.

Task III was the transparency analysis phase. During this phase, the data collected in Tasks I and II defining the transparency characteristics was assembled and analyzed to ascertain which design parameters are the most cost effective and those that are the least cost effective. The data was categorized by aircraft transparency type, mission and design characteristics, and a determination of the types of failures and relative frequencies was established. In addition, a comparison of the reliability and maintainability costs for each aircraft type with the basic design parameters for each transparency was evaluated. From the foregoing, corrective programs for those transparency systems that are considered to be cost effective were identified and are being proposed to the Air Force.

STUDY AIRCRAFT

The list of aircraft included in this study is shown in figure 3. They represent a wide variety of transparency configurations and concepts including laminated glass panels, stretched acrylic, polycarbonates, composite panels, etc. The sampling of the study aircraft varies from very low speed helicopters to high-performance vehicles such as F-4, F-111, and F-15 fighter-type aircraft. The data on these selected aircraft provide a comprehensive coverage of maintenance problems that are being experienced in operational service.

TRANSPARENCY/SUPPORT SYSTEMS

The definition of transparency systems, as considered in this study, is listed in figure 4. They include three categories:

1. Transparency components

2. Interactive support systems

3. Support structures

The transparency components consist of the primary elements of windshield panel assemblies, canopy transparency and frame assemblies, and cabin windows. The interactive support systems include only the major components of the subsystem. For example, sensors, bus bars, controllers, and toggle switches for anti-icing systems are included; integral and adjacent ducts, diffusers, and control valves for defogging; actuators, links, and latches are also included. Ancillary items such as wiring, switches, tubing, etc, are not included. Support structure considers only those members that form an edge member, adjacent contact with edge member, or part of a frame assembly.

BOMBERS
- B-52, B-57, AND FB-111

ATTACK
- A-7D AND A-37

CARGO/TRANSPORT
- C-5, C-9, C-130, C/KC-135, AND C-141

FIGHTERS
- F-4, F-15, F-105, AND F-111

TRAINERS
- T-37, T-38, AND T-39

OBSERVATION/UTILITY
- O-2 AND OV-10

HELICOPTERS
- CH-3, CH-53, AND UH-1

Figure 3. Study Aircraft

COMPONENTS

1. WINDSHIELDS
2. CANOPIES
3. WINDOWS

INTERACTIVE SUPPORT SYSTEMS

1. ANTI-ICING
2. DEFOGGING
3. RAIN REMOVAL
4. OPERATING AND ACTUATION
5. PRESSURIZATION

SUPPORT STRUCTURES

1. FRAMES
2. POSTS
3. LONGERONS & SILLS

Figure 4. Aircraft Transparency Systems

SECTION III

TRANSPARENCY SYSTEMS LOGISTICAL COSTS

K051 LOGISTICAL SUPPORT COSTS

The K051 Increased Reliability of Operational Systems (IROS) Program was developed to identify those components, subsystems, or equipment items that have disproportionate demands on the logistical resources. The objective of this program is to quantitatively access, predict, and improve the effectiveness of weapon or support systems. This is accomplished by providing a means of tracking the performance, reliability, maintainability of these systems to measure the effect on safety and logistical support. IROS-generated cost data includes inputs from both the air logistics centers (ALC), also referred to as the depot, and the operational Air Force bases (OAFB).

The elements that make up the system for tracking of logistical support cost are shown below. The logistics support cost (LSC) includes:

1. FMC - Field Maintenance Cost
2. SRC - Specialized Repair Cost (Depot)
3. PSC - Packaging and Shipping Cost
4. CON-C - Condemnations Cost (Spares)

The basis upon which the costs are assembled is equated in figure 5, which briefly provides the terms and definitions for these costing data.

IROS data are generally presented in common terms such as operator hour, cost per flying hour, and other applicable time and cost relationships. It is frequently used in establishing cost-effective fixes which will repay their cost in reduced logistics support. For this reason, IROS data was used as the initializing parameter in the determination of the corrective programs generated in the Task III transparency analysis phase.

LSC FOR STUDY AIRCRAFT

Since the K051 IROS listing is the focal point for the proposed design improvement trades, a tabulation of the logistical support cost for the 20 study aircraft are presented in this section. These data were extracted from microfiche provided by the Air Force Logistic Command, AFLC/LOLMA, and assembled in a computerized accounting file.

Figures 6 and 7 are samples of computer printouts for the T-39 aircraft. Figure 6 is a summary of the annual cost listing by quarter, headed by the current quarter followed by the previous three quarters. For this sample, the annual expenditure for January 1976 through June 1977 was $263,082 for the maintenance of the total T-39 transparency system. Figure 7 presents an example of the K051 tabulation that includes data for the most costly item of the transparency system. The anti-icing system controller identified by the AFM 66-1 MDCS work unit code (WUC) number is ranked number one as the highest cost item of the transparency system, and ranked number forty-eight as the most costly maintenance item of the total aircraft system.

It should be noted that the K051 microfiche lists the cost on an average dollars per month basis for each quarter. Since each quarter contains three months, the sum of quarterly listings must be multiplied by three to arrive at the total annual cost. For example the total cost of WUC 41535 (controller) is three times the sum of the average dollars per month for the four quarters, or 3 x $18,856 = $56,568 per year. It should also be noted that the totals and elements of total cost are presented on a yearly basis. The average monthly cost was retained for direct traceability to K051 microfische.

ANNUAL SUPPORT COSTS

The annual and projected maintenance costs depicted in figures 1 and 2 were assembled and categorized from the summary of maintenance and logistical support costs shown in table 1. These data were gathered for the purpose of providing a quick reference to the most widely used logistical cost comparison factors. The cost data were obtained from the K051 process previously described, and the flight hours from the AFM 66-1 data tapes. The process utilized to split the maintenance data from the AFM 66-1 data tapes is Rockwell's "Maintenance Analysis Model Program (MAMS)". This process is discussed at greater length in Volumes II and III of this report.

In making these comparisons care must be given to ensure that costs and flight hours are for the same timespan. The maintenance data contained in the AFM 66-1 tapes covered an 18-month timespan from January 1976 through June 1977. Consequently any comparison of cost and flight hours must be adjusted for equivalency in timespan.

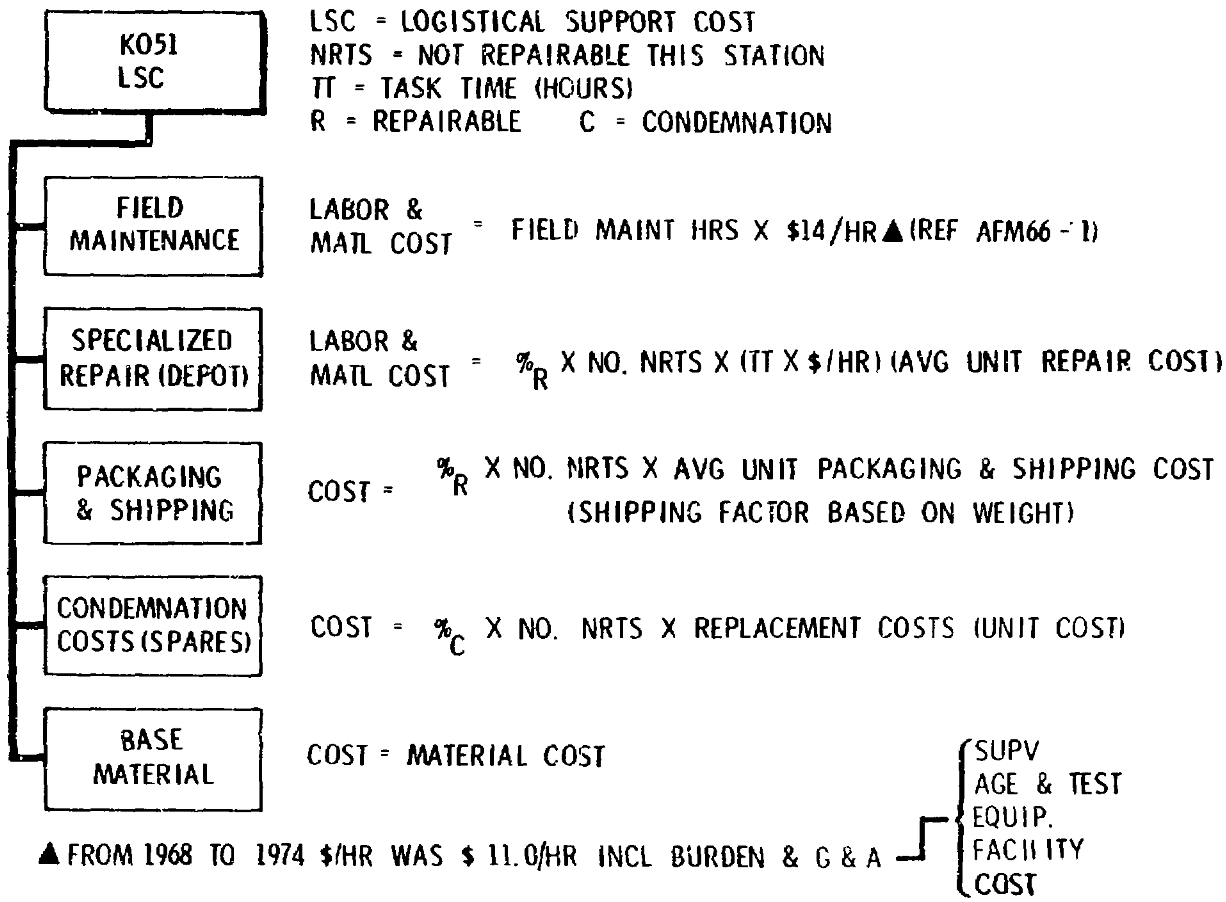


Figure 5. K051 IROS-Improved Reliability Operational System

MODEL: T-39 LOGISTICAL SUPPORT COST K051 DATA SET: 1-76/6-77

*** TOTALS ***

	QTR	F-M-C	S-R-C	P-S-C	CON-C
CUR	65511				
1ST	62517				
2ND	63495				
3RD	71559				
YEAR	263082	80935	15259	337	5111

WUC:	WORK UNIT CODE
%T/S:	PERCENT OF TOTAL TRANSPARENCY COST
T/S RANK:	TRANSPARENCY COST RANK
A/C RANK:	TOTAL AIRCRAFT COST RANK
F-M-C:	FIELD MAINTENANCE COST
S-R-C:	SPECIAL REPAIR COST
P-S-C:	PACKAGING AND SHIPING COST
CON-C:	CONDEMNATION COST

Figure 6. Sample K051 Logistical Cost Summary

MODEL: T-39 LOGISTICAL SUPPORT COST K051 DATA SET: 1-76/6-77 PAGE 6

WUC	DESCRIPTION	QTR	AVG. $/MO	%T/S	RANK T/S	RANK A/C	F-M-C	S-R-C	P-S-C	CON-C
41532	SENSING ELEMENT	CUR	110							
		1ST	154							
		2ND	139							
		3RD	283							
	YEARLY TOTAL:		2058	.78	20	669	0	0	0	0
415330	OVER HEAT THERMO SWITCH	CUR	53							
		1ST	0							
		2ND	129							
		3RD	146							
	YEARLY TOTAL:		984	.37	29	808	0	0	0	0
41535	CONTROLLER	CUR	4153				5154	5387	99	1820
		1ST	3408							
		2ND	4769				3791	9872	223	821
		3RD	6526							
	YEARLY TOTAL:		56568	21.50	1	48	8945	15259	322	2241
41536	SWITCH	CUR	86							
		1ST	42							
		2ND	86							
		3RD	47							
	YEARLY TOTAL:		783	.30	30	761	0	0	0	0
41537	CONTROLLER T-39B	CUR	19							
		1ST	9				1105			
		2ND	1207				160			
		3RD	0							
	YEARLY TOTAL:		3705	1.41	11	1015	1265	0	0	0

Figure 7. Sample K051 Logistical Cost Tabulation

TABLE 1. ANNUAL TRANSPARENCY SYSTEM LOGISTICAL SUPPORT COSTS

A/C type	Annual LSC cost ($)	Annual flight hours (1977)	$/flt hr
Cargo/transport			
C-5A	50,610	45,519	
C-9A	22,710	24,237	
C-130A	73,122	38,355	
C-130B	79,548	47,001	
C-130E	158,574	217,041	
C-130H	34,482	24,477	
C/KC-135A	924,228	201,867	
C-141A	409,028	287,946	
Total cargo/transport	1,852,302	886,443	2.09
Fighters			
F-4C	171,660	58,944	
F-4D	241,053	99,810	
F-4E	254,343	163,707	
RF-4C	251,535	69,447	
F-15A	520,943	30,408	
F-105	77,241	43,067	
F-111A	39,840	14,847	
F-111D	46,137	14,162	
F-111E	32,787	18,978	
F-111F	55,536	21,075	
Total fighters	1,491,075	534,445	2.79
Trainers			
T-37B	149,163	277,068	
T-38A	717,486	332,778	
T-39A	263,082	123,579	
Total trainers	1,129,731	733,425	1.54
Helicopters			
CH-3	213,312	26,091	
CH-53	52,947	13,761	
UH/TH-1F, 1P	73,431	73,640	
Total helicopters	339,690	113,492	2.99
Bombers			
B-52G	138,348	64,431	
B-52H	93,000	36,936	
B-57	34,527	19,552	
FB-111A	49,635	17,463	
Total bombers	315,510	138,382	2.28
Attack			
A-7D	233,283	102,726	
A-37	41,463	31,566	
Total attack	274,746	134,292	2.05
Observation			
O-2	58,461	72,432	
OV-10A	35,478	40,574	
Total observation	93,939	113,006	0.83
Total LSC for 20 study A/C	5,496,993	2,653,485	

SECTION IV

CURRENT MAINTENANCE PROBLEMS

FIELD AUDIT COMMENTS

During the field audit surveys, many discussions were held with maintenance personnel to evaluate procedures and to identify problems and testing capabilities. These people were also asked to relate their experiences in the inspection, repair, and replacement of transparencies, and to describe the impact of environmental and weathering factors that contribute to the recorded failures.

The following is a collection of remarks concerning the most common transparency system maintenance problems:

SEALANTS AND AEROSMOOTHING

One universal complaint of the operational bases was the long sealant cure time required after replacement of windshields or canopies. Depending on the sealant material and the transparency installation, approximately 24 to 72 hours of cure time are required. A great deal of pressure is imposed on maintenance personnel for earlier return of aircraft to flight status.

SCRATCHING/CRAZING/DELAMINATIONS

These are the most prevalent complaints of flight crews regarding the optical qualities of transparencies. When a complaint is registered, Quality Control will review Technical Order Manual criteria to ascertain if replacement of the component is required. In instances where these criteria fall within a gray area, and a decision for replacement is judgemental, a flight test crew will be consulted to determine final disposition.

MOISTURE PENETRATION OF TRANSPARENT PANELS

The onset of peripheral delaminations is generally caused by moisture penetration of the edge members. Since this type of delamination is most prevalent, maintenance people believe that improved edge attachment member sealing would greatly reduce this type of failure.

TRANSPARENCY CRACKS

These are principally caused by stress concentrations due to the misalignment of holes in the transparent panel and edge attachment members. In the cases where replacement panels are back-drilled to ensure proper alignment, the drilling process will sometimes cause local stress concentrations. Improvements in these areas are needed.

ELECTRICAL ANTI-ICING SYSTEMS

In many aircraft with this type of system, the activation of deicing operation is initiated by a simple three-position toggle switch. Under conditions requiring the use of the anti-icing system, an overtemperature condition brought on by a faulty controller may cause the cracking of the outer ply. This problem is also attributed to faulty temperature-sensing devices. The unanimous opinion of people in the field is that significant reduction in maintenance man-hours can be achieved by improved design of these items.

CANOPY RIGGING AND ALIGNMENT

The replacement of canopy-type transparencies is the cause of an extremely large expenditure of man-hours. The problem is one of adjusting to a wide range of tolerances when the canopy assembly is removed from aircraft for rework. To maintain proper interface with position of the windshield arch and its hinging and attaching points, a complicated series of measurements are made to accomplish proper fit. In some aircraft, this procedure is so difficult that canopies must be sent to the depot where tooling fixtures, accurate enough to control tolerances, are available. This operation is, of course, costly in man-hours and time required for handling and logistics stocking.

FASTENER ATTACHMENT

The replacement of transparent assemblies is often complicated by a large variety of types and sizes of fasteners. In many windshield configurations, access to the attachment fasteners, particularly the lower row, is severely restricted. Consequently, selection of appropriate fasteners could reduce installation time and problems.

ACCESS TO WINDSHIELD PANELS

In some aircraft, access to windshields requires the removal of instrument glare shields and associated wiring and plumbing. Two aircraft also required the cutting of electrical wire bundles to complete the removal of the shield assembly. In some fighter aircraft, access to the instrument area is most easily achieved through the removal of windshield side panels. It was suggested that quick-type disconnects be incorporated to ease the removal of glare shields.

Additional transparency-oriented maintenance problems are discussed in the procedures section of Volume II.

TRANSPARENCY SYSTEM COMPARISON

The general statistics for the current maintenance problems that were briefly discussed in the preceding paragraphs of this section are depicted in figure 8. It presents the most utilized parameters that are used as a basis of comparison for transparency systems. The parameters include:

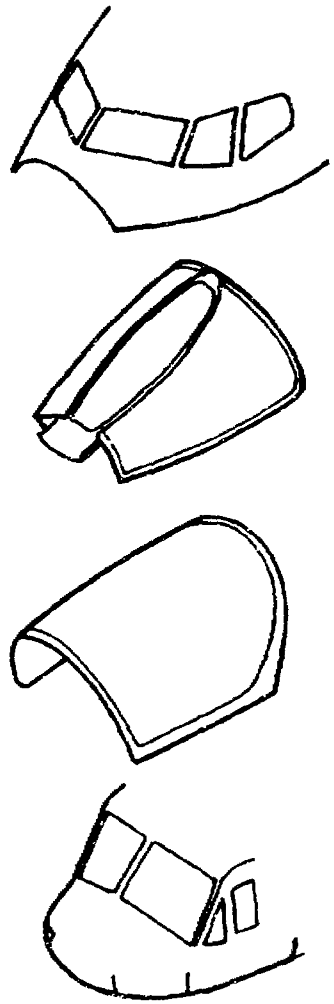
1. Mean time between failures (MTBF)

2. Maintenance man-hours per flight hour

3. Logistical support cost in dollars per flight hour

These statistics were gathered from data contained in references 1 and 2; and from data generated and assembled from this study. The intent of these data is to provide an overview and basis of general comparison of the various transparency system concepts contained in the 20 study aircraft. It will be noted that range of values shown are the extremes of the values from the K051 and AFM 66-1 data.

Examination of the K051 logistical support costs for many of the study aircraft, as shown in the sample tabulations in figures 6 and 7 and summarized in table 1, indicates that the distribution of the field maintenance, special repair, packaging/shipping and condemnation costs are incomplete. This conclusion was drawn from a survey of the K051 tabulations, and from data obtained from the field audits. It is believed that these costing elements are accounted for in the totals shown in the column listing the average dollars per month for the current and three preceding quarters. Although some of these values are suspect, they were left unchanged to maintain consistency for basis of comparison. These data, however, were adjusted when used in the trade studies developed in Volume III. This was done to ensure the validity of the trade study, where known special repair activity or a more accurate description of maintenance was identified.



	MTBF (HR)	MAINT MANHOURS/ FLT HR	LOGISTICAL SUPT COST (S/FLT HR)
Cargo/Transport Windshields	915-4400	.055-.448	0.93-4.58
Fighter Type Windshields	175-1275	.036-.137	0.61-.95
Fighter Type Canopies	575-1410	.074-.275	1.16-1.89
Helicopter Windshields	150-300	.099-.235	0.99-8.2

Figure 8. Transparency System Comparison

SECTION V

SUMMARY OF TRADE STUDIES

TRADE STUDY OBJECTIVE

The primary objective of this study is to identify and recommend corrective programs to transparency systems that will reduce Air Force Logistics Command (AFLC) ownership cost for current inventory aircraft. Rockwell has selected five transparency system areas, whose annual maintenance, and logistical support cost are considered to be significant. In view of the effort required to research, analyze, and assemble these data, the scope of the program permitted the development of only five design improvement studies. The corrective programs reviewed resulted in the following trade studies.

1. T-39A Windshield Anti-icing Controller Redesign

2. KC-135A Boom Door and Sighting Window Redesign

3. B-52G/H Windshield and Window Redesign

4. C-141A Windshield Redesign

5. T-38A Canopy Locking Mechanism Redesign

TRADE STUDY SUMMARY

The results of the trade studies presented herein were based on a comparison considering a 10-year life cycle cost. The studies conducted indicate that appreciable savings in the field maintenance and other logistical support costs for the proposed design changes are possible. The principal factors traded are the projected cost of maintaining the present concept against the redevelopment, replacement, and maintenance costs for the redesigned concept. The summary of these estimated savings are:

Trade Study	Average Annual Cost Savings
1. T-39A Windshield Anti-icing Controller Redesign	$ 114,087
2. KC-135A Boom Door and Sighting Window Redesign	$ 42,836
3. B-52G/H Windshield and Window Redesign	$ 152,659
4. C-141A Windshield Redesign	$ 208,124
5. T-33A Canopy Locking Mechanism Redesign	$ 106,416

If all five condidate trades are implemented, the annual saving would approach $625,000 for the proposed changes.

TRADE STUDY CRITERIA

The ground rules imposed in the selection of these candidate improvements were to identify those aircraft having a high annual expenditure in maintenance of transparency systems. A second consideration was the identification of the components having a large frequency of failure. Another consideration in the selection process is the relative importance the aircraft maintains in the total posture of the Air Force inventory.

TRADE STUDY DESCRIPTIONS

The trades shown in this section are recapitulations of the analysis contained in the transparency analysis of Volume III. A very brief summary of trade results are presented in the following pages of this section.

T-39A WINDSHIELD ANTI-ICING CONTROLLER REDESIGN

Examination of the K051 logistical support costs indicates that the windshield anti-icing controller ranks number one as the high cost contributor in transparency system maintenance costs. The controller presently used is a germanium semiconductor-type controller providing a time delay device to prevent thermal shock of windshield pane during cold ambient startup of windshield anti-icing (figure 9).

Failures detected from AFM 66-1 data and from Rockwell field service bulletins indicate that approximately 12 percent of the failures associated with cracking and delaminations can be attributed to the failed controller (figure 10). It is proposed that a modern solid-state-type controller be substituted. As a result of this proposed change, an annual saving of $92,200 for the controller substitution, with an accompanying fallout saving of $21,900 for windshield panels, can be realized. Table 2 summarizes the costs detailed in Volume III. The projected escalation factors used in pricing the spares and repair costs were obtained from reference 3, USAF "Cost and Planning Factors," AFR-173-110, Volume I, dated 6 February 1975.

KC-135A BOOM DOOR AND SIGHTING WINDOW REDESIGN

The boom operator's sighting door window (figure 11) provides access to an hydraulic accumulator. This window must be removed on a daily basis to service the accumulator and related equipment. As a result of these frequent removals, the sighting window is inadvertently damaged (figure 12).

To minimize the damage and costs inflicted, it is proposed that the window be hinged to reduce the ground handling problem. The annual reduction in cost ($42,836) is summarized in table 3.

B-52G/H WINDSHIELD AND WINDOW REDESIGN

A survey of B-52 transparency maintenance activity indicates that the windshields and windows, most of which are shown in figure 13, contribute 68 percent of the total logistical cost. Of these failures (figure 14), an estimated 30 percent are associated with delaminations, cracking, chipping, and deterioration of the panel assemblies. Data from both ALC and AFM 66-1 point to the anti-icing controller as being a contributing factor to this type failure. Discussion with ALC indicates that removal of the instrument glare shield to gain access to windshield attachment is also a high cost contributor.

Therefore, to reduce the cost associated with these failures, it is proposed that the panel assemblies be modified to incorporate a more flexible interlayer and a redesigned edge seal. It is also recommended that an improved controller and glare shield be incorporated. Refer to Volume III for a description of these modifications. The incorporation of these proposed changes are estimated to result in an annual saving of $152,659. (Refer to table 4.)

C-141A WINDSHIELD REDESIGN

A review of the failure modes reveals that the windshield panels, most of which are shown in figure 15, account for approximately 60 percent of the total cost of maintaining the C-141A transparency system. Of these failures (figure 16), an estimated 30 percent are associated with delaminations, cracking, chipping, and deterioration of the panel assemblies. Data from both ALC and AFM 66-1 point to environmentally induced cracks and delaminations as being contributing factors to the failure of these windshields. Discussion with ALC also indicates that removal of the instrument glare shield to gain access to windshield attachment is also a high cost contributor.

Therefore, to reduce the cost associated with these failures, it is proposed that the panel assemblies be modified to incorporate a more flexible interlayer and a redesigned edge seal. It is also recommended that an improved glare shield be incorporated. Refer to Volume III for a description of these modifications. The incorporation of these proposed changes are estimated to result in an annual saving of $208,124 (refer to table 5).

T-38A CANOPY LOCKING MECHANISM REDESIGN

A high cost contributor of the T-38A canopy installation (figures 17 and 18) is due to rigging tolerances associated with the locking mechanism. This problem is traced to the deterioration of potting compound in the splined connection of the latching hook. The accumulation of backlash that can occur at 16 locations thereby causes canopy locking problems.

The proposed fix for this problem is to redesign the lock assembly to provide a more positive attachment to completely eliminate backlash. The incorporation of the proposed change is estimated to result in an annual saving of $106,416. (Refer to table 6.)

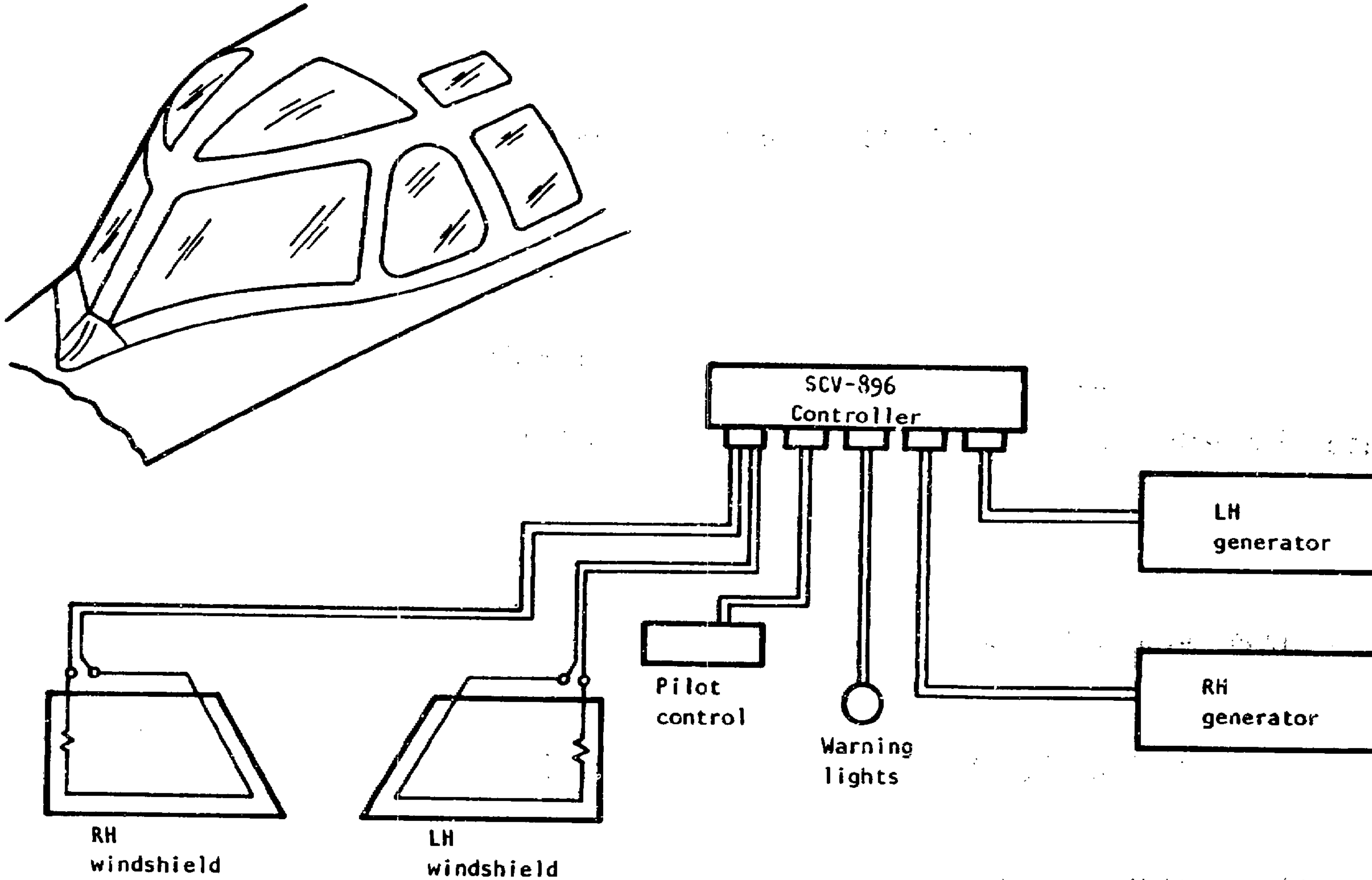


Figure 9. T-39A Windshield Arrangement and Anti-icing System Diagram

COMPONENT	FAILURE MODES	CANDIDATE IMPROVEMENTS
•ANTI-ICING SYSTEM CONTROLLER	-INTERNAL FAILURE -FAILED TO OPERATE -INCORRECT VOLTAGE	-INCORPORATE IMPROVED SOLID-STATE HEAT CONTROLLER -IMPROVE WARNING DEVICES
•WINDSHIELD	-CRACKED -DELAMINATED -CHIPPED	-INCORPORATE IMPROVED HEAT CONTROLLER

Figure 10. Failure Analysis T-39A Windshield System

TABLE 2. DESIGN IMPROVEMENT TRADE STUDY 1 — T-39A WINDSHIELD ANTI-ICING CONTROLLER REDESIGN

Present concept		Redesigned concept	
Item	10-yr life cycle cost	Item	10-yr life cycle cost
Field maintenance cost		Replacement cost	
Controller	$ 702,090	Nonrecurring - dvmt & qual	$ 125,420
Windshield	858,510	- T.O. revision	7,500
		Recurring - controller replacement	530,694
Special repair			
Controller	1,126,402	Field maintenance	
		Controller	242,869
Spares		Windshield	755,490
Windshield	231,200	Spares	
		Windshield	115,360
Total present concept cost	$2,918,202	Total redesigned concept cost	$1,777,333
10-year LCC saving			$1,140,869
Annual LCC saving		$114,087	

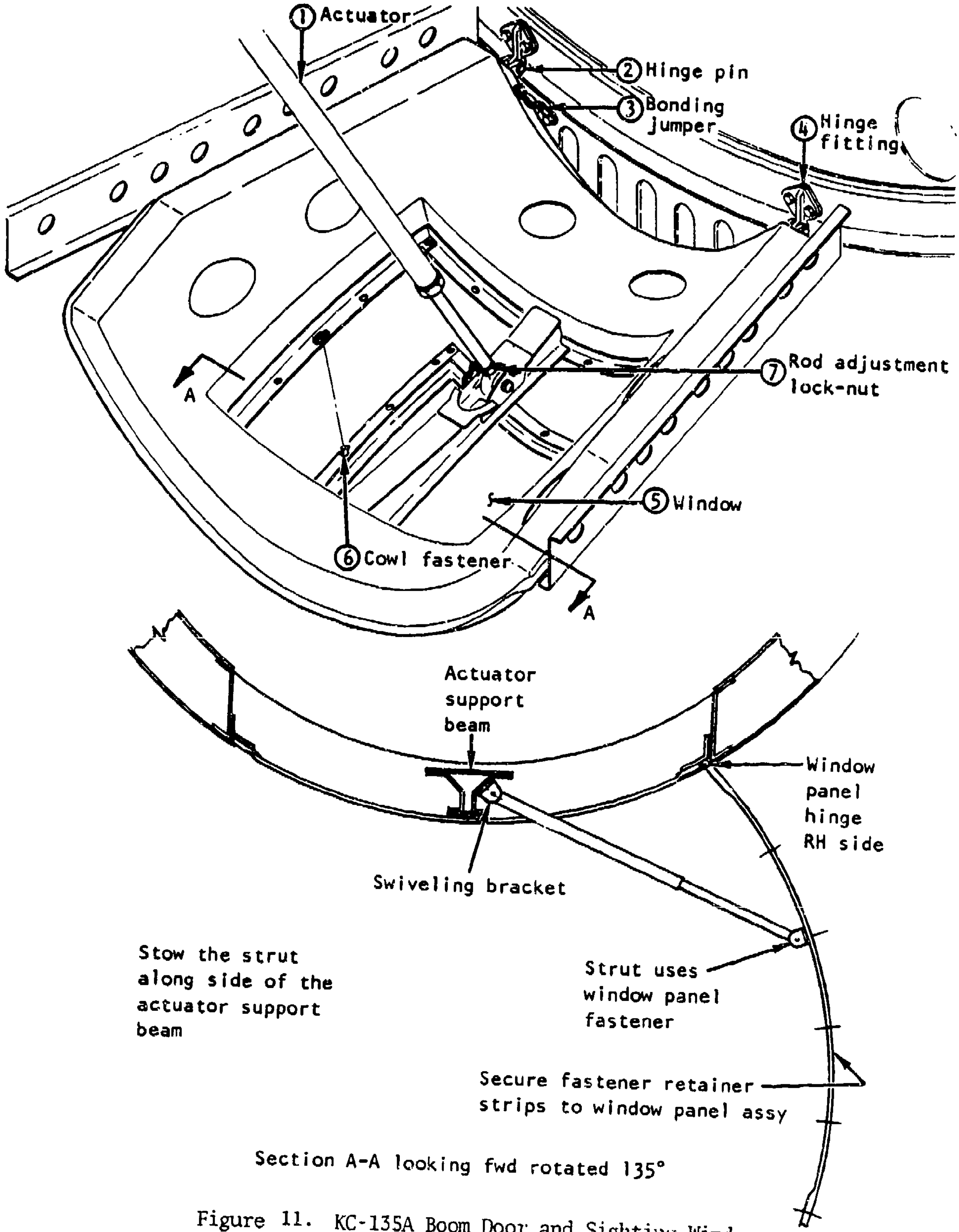


Figure 11. KC-135A Boom Door and Sighting Window

COMPONENT	FAILURE MODES	CANDIDATE IMPROVEMENTS
•BOOM SIGHTING DOOR WINDOW	-NO DEFECT	-HINGE WINDOW PANEL TO PROVIDE QUICK ACCESS (1)
	-LOOSE/DAMAGED/MISSING BOLTS, NUTS, ETC	-USE IMPROVED FASTENERS
		-RETAIN PARTS THAT ARE REMOVED FOR SERVICING
	-CRACKED -CHIPPED -SCRATCHED	-USE HINGE TO SECURE REMOVABLE WINDOW TO AIRFRAME
•BOOM SIGHTING WINDOW	-DELAMINATED	-IMPROVE FLEX INTERLAYER
	-CRACKED	-IMPROVE SEALING
	-CHIPPED	-USE "ZEE" STRIP, EDGE FRAME
		-IMPROVE ANTI-ICE SYSTEM

(1) WINDOW IS USED AS AN ACCESS PANEL TO SERVICE SUBSYSTEMS.

Figure 12. Failure Analysis KC-135 Boom Sighting Window

TABLE 3 DESIGN IMPROVEMENT TRADE STUDY 2 — KC-135A BOOM DOOR AND SIGHTING WINDOW REDESIGN

Present concept		Redesigned concept	
Item	10-yr life cycle cost	Item	10-yr life cycle cost
Field maintenance		Replacement cost	
Boom door assy	$ 760,924	Nonrecurring - engrg & tooling	$ 27,080
		- TCTO	13,403
Spares		Recurring - boom door kits	45,440
Boom door assy	719,150	- boom door instl cost	116,100
		Field maintenance	
		Boom door assy	263,338
		Spares	
		Boom door assy	626,838
Total present concept	$1,480,074	Total redesign concept	$1,051,716
10-year LCC saving			$ 428,358
Annual LCC saving		$42,836	

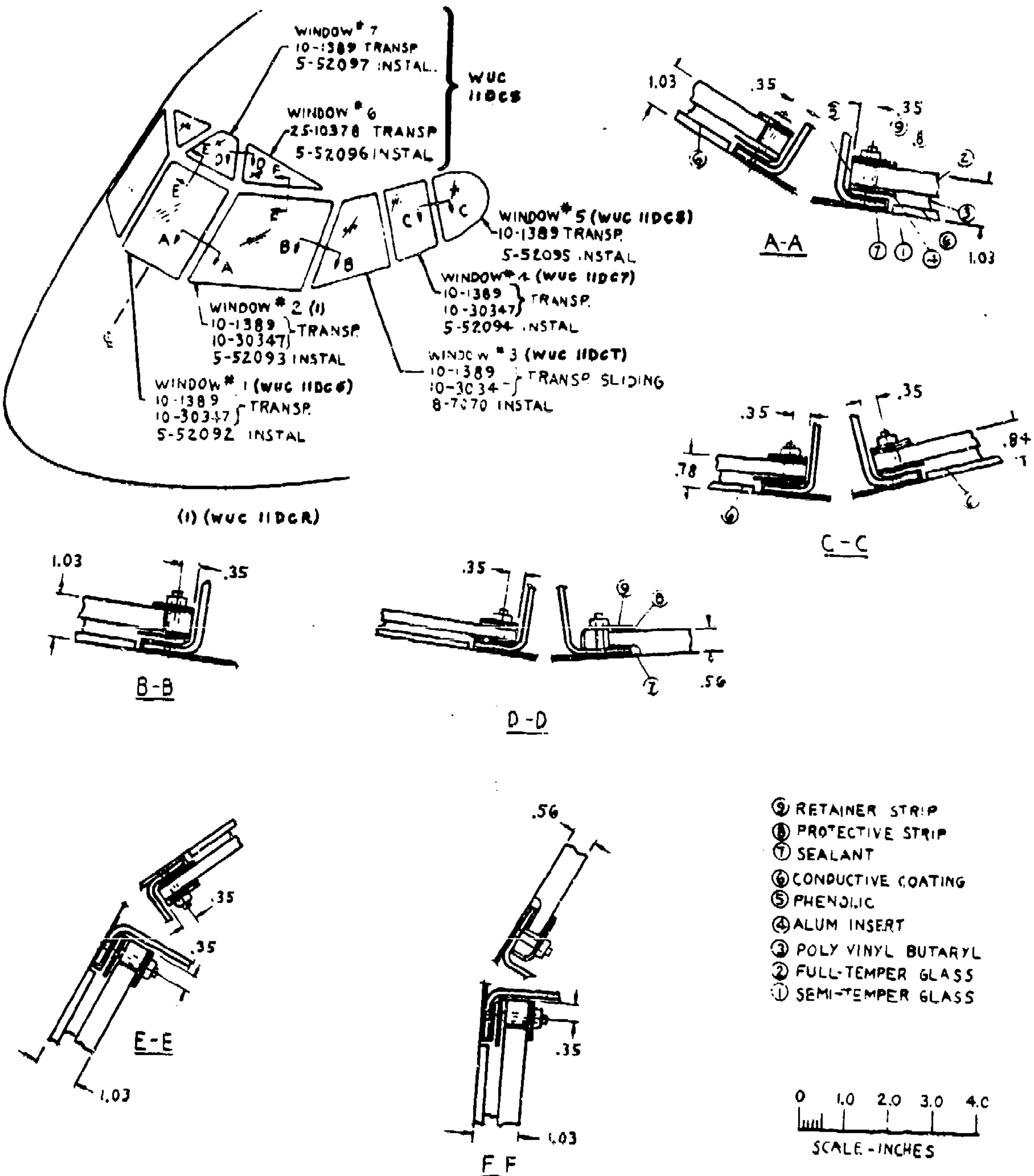


Figure 13. B-52G/H Windshields and Windows

COMPONENT	FAILURE MODES	CANDIDATE IMPROVEMENTS
•WINDSHIELD PANEL NO. 1 •WINDSHIELD PANEL NO. 2 •SLIDING WINDOW PANEL •WINDOW PANEL NO. 4 •WINDOW PANEL NO. 5 •EYEBROW WINDOW PANELS	-CRACKED -DELAMINATED -CHIPPED	-IMPROVE FLEX INTERLAYER -IMPROVE SEALING -USE "ZEE" STRIP, EDGE FRAME -IMPROVE STRUCTURAL BACKUP SUPPORT -USE IMPROVED TEMPERATURE CONTROLLER
	-LOOSE/DAMAGED BOLTS, NUTS, ETC	-USE IMPROVED FASTENERS -MORE FREQUENT INSPECTIONS
•WINDSHIELD ANTI-ICE TEMPERATURE CONTROLLER	-INTERNAL FAILURE -FAILED TO OPERATE	-USE IMPROVED SOLID-STATE TEMPERATURE CONTROLLER

Figure 14. Failure Analysis B-52G/H Windshield and Windows

TABLE 4. DESIGN IMPROVEMENT TRADE STUDY 3 — B-52G/H WINDSHIELD AND WINDOW REDESIGN

Present concept		Redesigned concept	
Item	10-yr life cycle cost	Item	10-yr life cycle cost
Field maintenance cost		Replacement cost	
Windshield and window	$1,975,503	Nonrecurring - tooling	$ 66,700
Controller	774,064	- engrg	67,310
Glareshield	399,110	- certif & tests	283,500
Special repair		- controller qual	140,000
Controller	104,041	Recurring - W/S retrofit	2,303,766
Spares		- controller replmt	194,175
Windshield and window	4,162,878	- glareshield replmt	46,217
Controller	199,980	Field maintenance cost	
		Windshield and window	1,078,625
		Controller	387,032
		Glareshield	79,822
		Spares	
		Windshield and window	1,290,500
		Controller	155,339
Total present concept costs	$7,615,576	Total redesigned concept cost	$6,092,986
10-year LCC saving			$1,526,590
Annual LCC saving		$152,659	

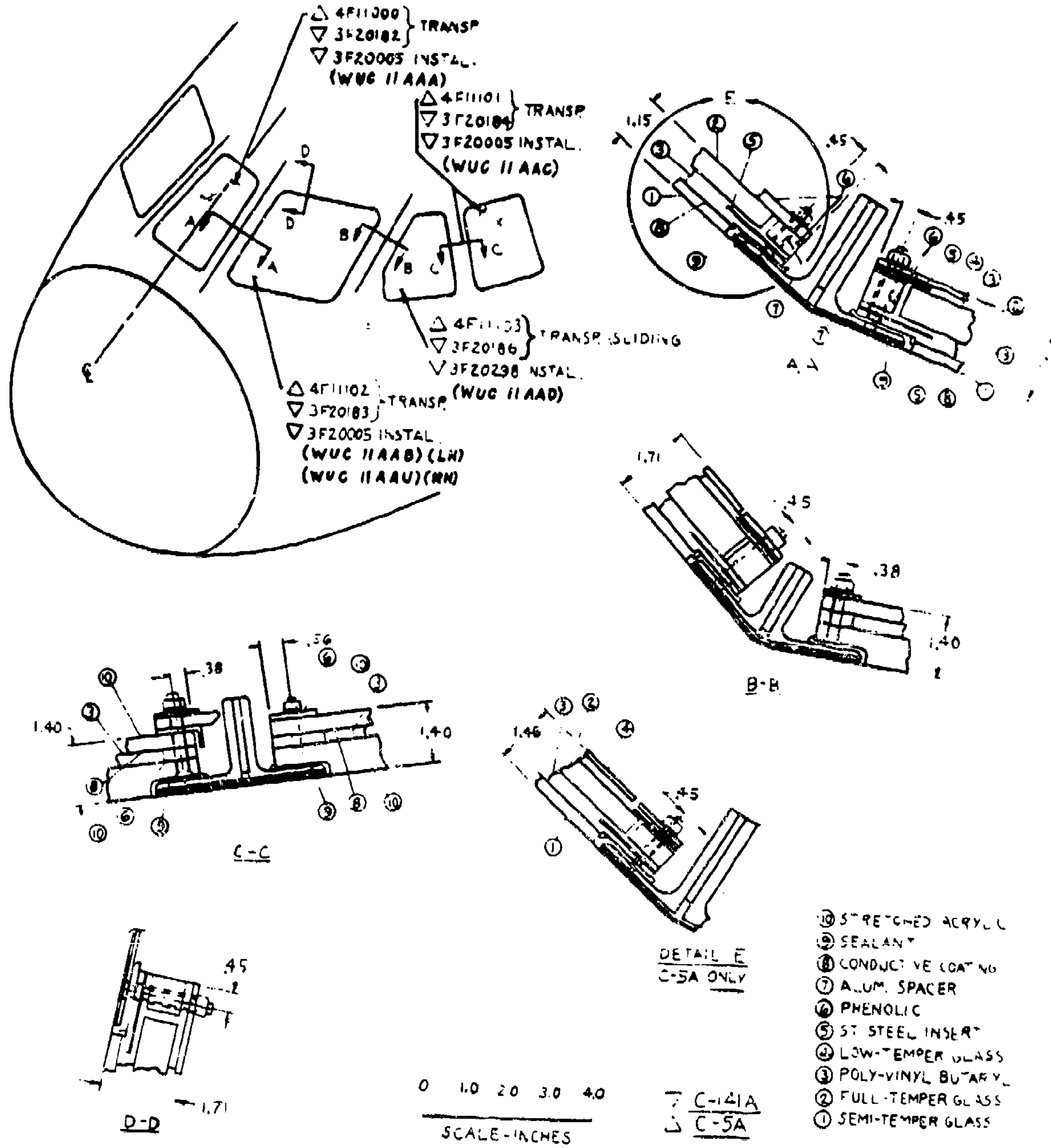


Figure 15. C-141A Windshields

COMPONENT	FAILURE MODES	CANDIDATE IMPROVEMENTS
•WINDSHIELD CENTER PANEL •WINDSHIELD MAIN PANEL	-CRACKED -DELAMINATED	-IMPROVE FLEX INTERLAYER -IMPROVE SEALING -USE "ZEE" STRIP, EDGE FRAME -IMPROVE STRUCRUAL BACKUP SUPPORT
	-LOOSE/DAMAGED BOLTS, NUTS, ETC	-USE IMPROVED FASTENERS
•CLEAR VISION PANEL	-LEAKING	-IMPROVE WEATHER/PRESSURE SEAL INSTALLATION
	-SCORED/SCRATCHED	-USE IMPROVED HARD COATING
•WINDSHIELD SIDE PANEL	-DELAMINATED -CRACKED	-IMPROVE FLEX INTERLAYER -IMPROVE SEALING -USE "ZEE" STRIP EDGE FRAME -IMPROVE STRUCTURAL BACKUP SUPPORT
	-SCORED/SCRATCHED	-USE IMPROVED HARD COATING

Figure 16. Failure Analysis C-141A Windshield

TABLE 5. DESIGN IMPROVEMENT TRADE STUDY 4 — C-141A WINDSHIELD REDESIGN

Present concept		Redesigned concept	
Item	10-yr life cycle cost	Item	10-yr life cycle cost
Field maintenance cost		Replacement cost	
Windshield	$ 4,830,844	Nonrecurring - tooling	$ 53,360
Glareshield	302,758	- engrg	52,315
		- certif & qual	272,876
Spares		Recurring - W/S retrofit	3,941,826
Windshield	7,691,817	- glareshield replmt	44,704
		Field maintenance cost	
		Windshield	2,318,805
		Glareshield	60,551
		Spares	
		Windshield	3,999,745
Total present concept cost	$12,825,419	Total redesign concept cost	$10,744,182
10-year LCC saving			$ 2,081,237
Annual LCC savir		$208,124	

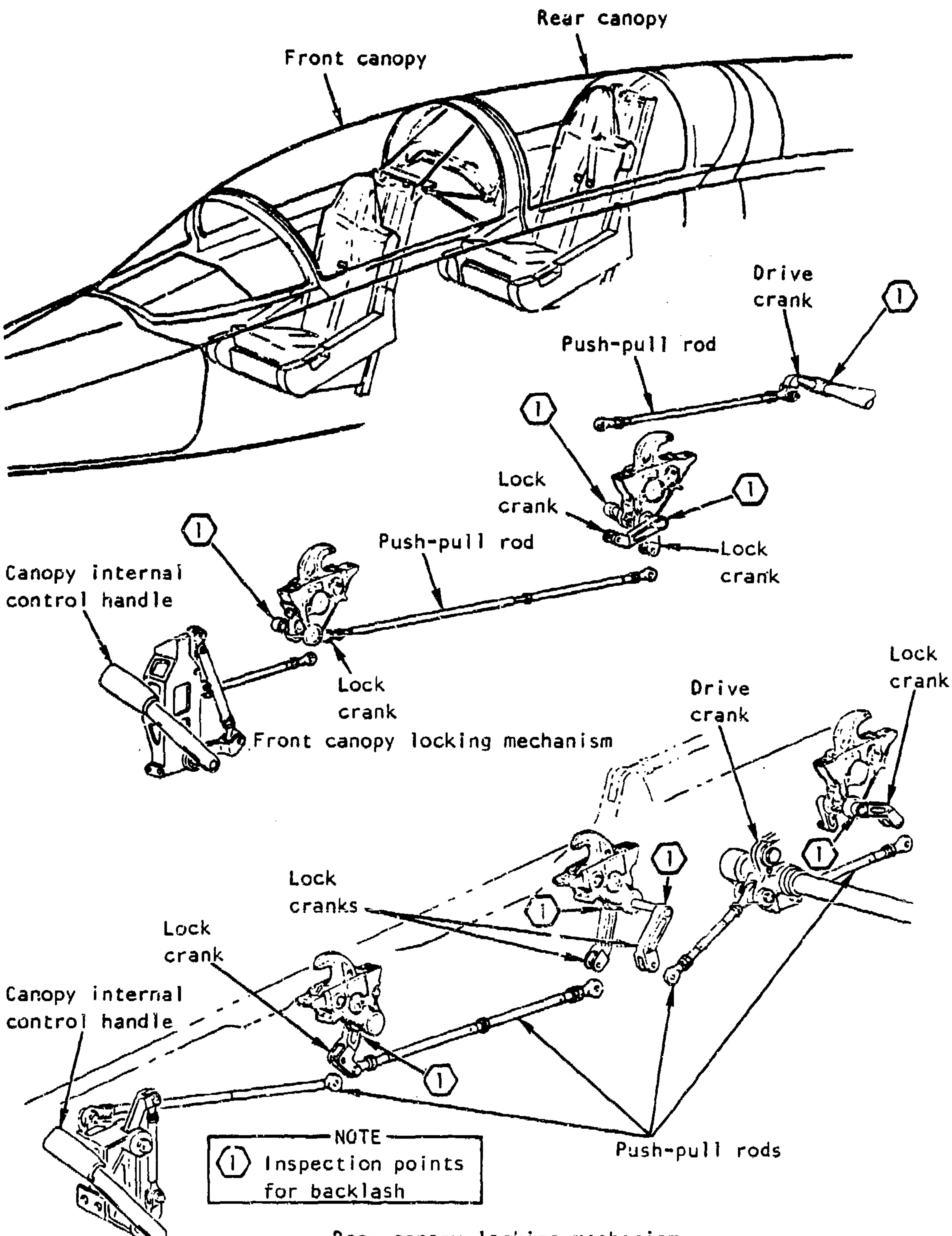


Figure 17. T-38A Windshield Canopy Locking Mechanisms

COMPONENT	FAILURE MODES	CANDIDATE IMPROVEMENTS
•CANOPY, FRONT STUDENT'S	-ADJUSTMENT AND/OR ALIGNMENT IMPROPER	-REINFORCE PARTS THAT WEAR EXCESSIVELY
•CANOPY, REAR INSTRUCTOR'S		-REDESIGN MECHANISM ARMS FOR MORE POSITIVE ATTACHMENT
		-ORIENTATION PROGRAM FOR NEW PERSONNEL
	-NO DEFECT	-SHOULD REDUCE AS OTHER HOW-MALS REDUCE
	-NO DEFECT, REMOVE FOR OTHER MAINTENANCE	

Figure 18. Failure Analysis T-38A Canopy Locking Mechanism

TABLE 6. DESIGN IMPROVEMENT TRADE STUDY 5 -- T-38A CANOPY LOCKING MECHANISM REDESIGN

Present concept		Redesigned concept	
Item	10-yr life cycle cost	Item	10-yr life cycle cost
Field maintenance cost		Replacement cost	
Canopy lock-down mech	$1,908,715	Nonrecurring - tooling	$ 233,600
Enclosure maintenance	4,112,474	- engrg	34,880
		- test & qual	16,000
		Recurring - replmt	276,800
		- install	84,770
		Field maintenance cost	
		Enclosure maint	4,112,474
		Canopy lock-down mech	198,506
Total present concept cost	$6,021,189	Total redesigned concept cost	$4,957,030
10-year LCC saving			$1,064,159
Annual LCC saving		$106,416	

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

During the conduct of this study, a number of conclusions were formed, relating to a very specialized field of maintainability and logistics: the "aircraft transparency system". These conclusions were formed as a result of direct contact with both the personnel from the military and from industry, and from the results of the analysis made in support of this program. Therefore, these observations are directed at giving the reader an appreciation of the problems in this field and to point out the benefits that the study results can achieve in the reduction of logistical costs.

OPTICAL QUALITIES

The physical nature of the transparent components makes it particularly susceptible to defects that degrade the desired optical qualities. During the field audit phase of this program, every aircraft surveyed had some sort of defect. The degree, of course, was dependent on the type aircraft, type of transparent concept, and operational environment. From this sampling, we can only conclude that many of the operational aircraft also has some sort of defect. The concern of maintenance personnel is to identify those problems that border on affecting the safety of flight, and find means of eliminating or at least minimizing these defects.

LOGISTICAL SUPPORT COST

The projections of estimated logistical support costs indicate that these expenditures are excessive. This conclusion is based on a sampling of the cost reduction contained in this study.

POTENTIAL CORRECTIVE PROGRAMS

The results of the design improvement studies coupled with life cycle cost analyses have conclusively shown that considerable savings in the maintenance of transparency systems can be realized. In many instances, such benefits can be gained for a relatively small initial expenditure that would provide the Air Force with a significant return on its investment. Considering the vast amounts currently being expended, the potential in cost reduction is considered to be significant.

DATA TRACKING SYSTEM

The analysis conducted in support of the corrective programs placed primary reliance on the data contained in the K051 IROS and AFM 66-1 data tracking systems. It was concluded that these data provided the most consistent baseline or reference for evaluation purposes. It should, however, be pointed out that in many cases data obtained from these processes lacked sufficient detail to permit identification of specific problems. The means for supplementing this data was through the information collected during the field audits. The onsite visitations, too, are considered to be an important factor in providing the ability to conduct a meaningful evaluation.

ORIENTATION TO WORK UNIT CODE

The necessity of providing more detailed descriptive information to support the type of analysis as presented in this report is deemed to be highly desirable. This, however, must be traded against the cost of expanding the level of descriptive breakdown in the work unit code structure. A possible compromise can be obtained by specialized training to give line personnel a better understanding of the importance of proper interpretation and assignment of effort to the existing work unit code.

TRAINING

Many of the transparency systems in the current inventory require a high degree of maintenance skills in servicing, and especially the implementation of the repair activity. The repair and replacement involves the handling of very expensive components. Certain aircraft require a rather high frequency of replacement rate, resulting in costly support of maintenance services. To provide the maximum effectiveness in the support of transparency maintenance, some bases are able to assign and maintain specialized personnel to support this activity. Although the repair manuals provide adequate instructions in the methods of repair and replacement of transparency components, the skills required to provide this service can be greatly improved by the infusion of maintenance techniques and procedures gained from other programs and other facilities. It is believed that greater use of specialized teams from both ALC and transparency suppliers can best provide this service. Improved training procedures could result in significant reduction in cost.

RECOMMENDATIONS

The study results of this program indicate that many options to achieve cost reduction are available. The extent to which the incorporation of these options should be implemented may require further study. But based on the life cycle cost trades developed for this program, Rockwell feels that many of these options can be initiated now with a very high degree of assurance of accomplishing improved reliability, reduced maintenance, and reduced cost. It is recommended that the following suggestions be considered to achieve this end.

1. Implement the design improvement studies conducted herein. Results indicate the suggested improvements in their entirety or partial elements are cost effective and will achieve the desired cost reductions.

2. Continue the search for cost reduction "corrective programs". Rockwell has developed a procedure that is a systematic approach to the

identification of the most meaningful problem areas. In the conduct of this study, Rockwell has established a comprehensive data base and developed the methodology to rapidly conduct cost-effective trades. In view of the extremely large expenditures forecast over the next 10 years, it is recommended that follow-on studies be implemented.

3. Although it has been stated that the AFM 66-1 MDCS is considered to be the most consistent baseline, or reference, for trade studies, it does not, however, provide adequate visibility to define a detailed level of failure mode. It is therefore recommended that a study be initiated to provide that level of definition.

4. A means of increasing the accuracy and validity of the existing AFM 66-1 (MDCS) system is to improve the input of interpretation of -06 work unit code manual. A combination of manual instructional improvement and training sessions with using personnel can improve the assignment of effort inserted in the AFTO-349, "Maintenance Data Collection Record".

5. During the field audits of various ALC's and operational bases, many contacts were established. In subsequent calls placed 2 to 3 months later, requesting additional information, found these contacts to be transferred to other organizations. On this basis it is concluded that it is difficult to maintain the highest level of required skills. It is therefore recommended that special training teams from the ALC be sent to improve the skill and expertise of personnel involved in transparency system maintenance.

CANDIDATE LIST OF DESIGN IMPROVEMENTS

The trade studies shown in Section V are some of the design improvements that were identified for five of the selected study aircraft. During the course of this program other design improvements in transparency system that can potentially reduce logistical support costs were also identified. The following are a listing of these improvements recommended for future consideration.

1. Develop quick-cure sealants and aerosmoothing compounds.

2. Design panel edge members to have greater resistance to moisture collection.

3. Expand development of dry seals.

4. Improve frame-to-glass (plastic) attachment to prevent local stress risers.

5. Improve uniformity of fastener type and size within periphery of panel.

6. Design frame-to-glass relative stiffness to avoid rigging, alignment, and tolerance problems.

7. Systems that require extensive removal of instrument shields, plumbing, wiring to gain access to attachment should have quick-disconnect provisions.

8. Improve sliding window mechanisms and controls.

9. Incorporate shock absorbers for sliding windows.

10. Continue to develop tougher coatings for transparencies subject to scratching.

11. Improve electronically operated anti-icing sensing and controller systems.

12. Modify flight control crew and flight line personnel uniform scratch-producing items.

13. Incorporate WUC number in -4 illustrated parts list.

14. Expand level of WUC description.

15. Expand and improve indoctrination of normal work unit code selection.

16. Improve contents of technical orders, to provide enhanced usability for maintenance personnel.

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